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Chemistry
Standard level
Paper 2

Friday 14 May 2021 (morning)

Candidate session number

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1 hour 15 minutes

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.



Answer **all** questions. Answers must be written within the answer boxes provided.

1. Iron may be extracted from iron(II) sulfide, FeS.

(a) Outline why metals, like iron, can conduct electricity. [1]

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(b) Justify why sulfur is classified as a non-metal by giving **two** of its chemical properties. [2]

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(c) Iron(II) sulfide, FeS, is ionically bonded.

(i) Describe the bonding in this type of solid. [2]

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(ii) State the full electron configuration of the sulfide ion. [1]

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(This question continues on the following page)



(Question 1 continued)

- (iii) Outline, in terms of their electronic structures, why the ionic radius of the sulfide ion is greater than that of the oxide ion. [1]

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- (iv) Suggest why chemists find it convenient to classify bonding into ionic, covalent and metallic. [1]

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- (d) The first step in the extraction of iron from iron (II) sulfide is to roast it in air to form iron (III) oxide and sulfur dioxide.

- (i) Write the equation for this reaction. [1]

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- (ii) Deduce the change in the oxidation state of sulfur. [1]

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- (iii) Suggest why this process might raise environmental concerns. [1]

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(This question continues on the following page)



16EP03

Turn over

(Question 1 continued)

(e) Explain why the addition of small amounts of carbon to iron makes the metal harder. [2]

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16EP04

2. Iron(II) sulfide reacts with hydrochloric acid to form hydrogen sulfide, H₂S.

(a) (i) Draw the Lewis (electron dot) structure of hydrogen sulfide. [1]

(ii) Predict the shape of the hydrogen sulfide molecule. [1]

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(b) In aqueous solution, hydrogen sulfide acts as an acid.

(i) State the formula of its conjugate base. [1]

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(ii) Saturated aqueous hydrogen sulfide has a concentration of 0.10 mol dm⁻³ and a pH of 4.0. Demonstrate whether it is a strong or weak acid. [1]

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(iii) Calculate the hydroxide ion concentration in saturated aqueous hydrogen sulfide. [1]

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(This question continues on the following page)



(Question 2 continued)

- (c) A gaseous sample of nitrogen, contaminated only with hydrogen sulfide, was reacted with excess sodium hydroxide solution at constant temperature. The volume of the gas changed from 550 cm^3 to 525 cm^3 .

Determine the mole percentage of hydrogen sulfide in the sample, stating one assumption you made.

[3]

Mole percentage H_2S :

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.....
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Assumption:

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16EP06

3. Magnetite, Fe₃O₄, is another ore of iron that contains both Fe²⁺ and Fe³⁺.

(a) Deduce the ratio of Fe²⁺:Fe³⁺ in Fe₃O₄. [1]

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(b) Iron exists as several isotopes.

(i) State the type of spectroscopy that could be used to determine their relative abundances. [1]

.....

(ii) State the number of protons, neutrons and electrons in each species. [2]

	Protons	Neutrons	Electrons
⁵⁴ ₂₆ Fe
⁵⁶ ₂₆ Fe ³⁺

(c) Iron has a relatively small specific heat capacity; the temperature of a 50 g sample rises by 44.4°C when it absorbs 1 kJ of heat energy.

Determine the specific heat capacity of iron, in J g⁻¹K⁻¹. Use section 1 of the data booklet. [1]

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(This question continues on the following page)



(Question 3 continued)

(d) In acidic solution, hydrogen peroxide, H_2O_2 , will oxidize Fe^{2+} .



(i) Write the half-equation for the reduction of hydrogen peroxide to water in acidic solution.

[1]

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(ii) Deduce a balanced equation for the oxidation of Fe^{2+} by acidified hydrogen peroxide.

[1]

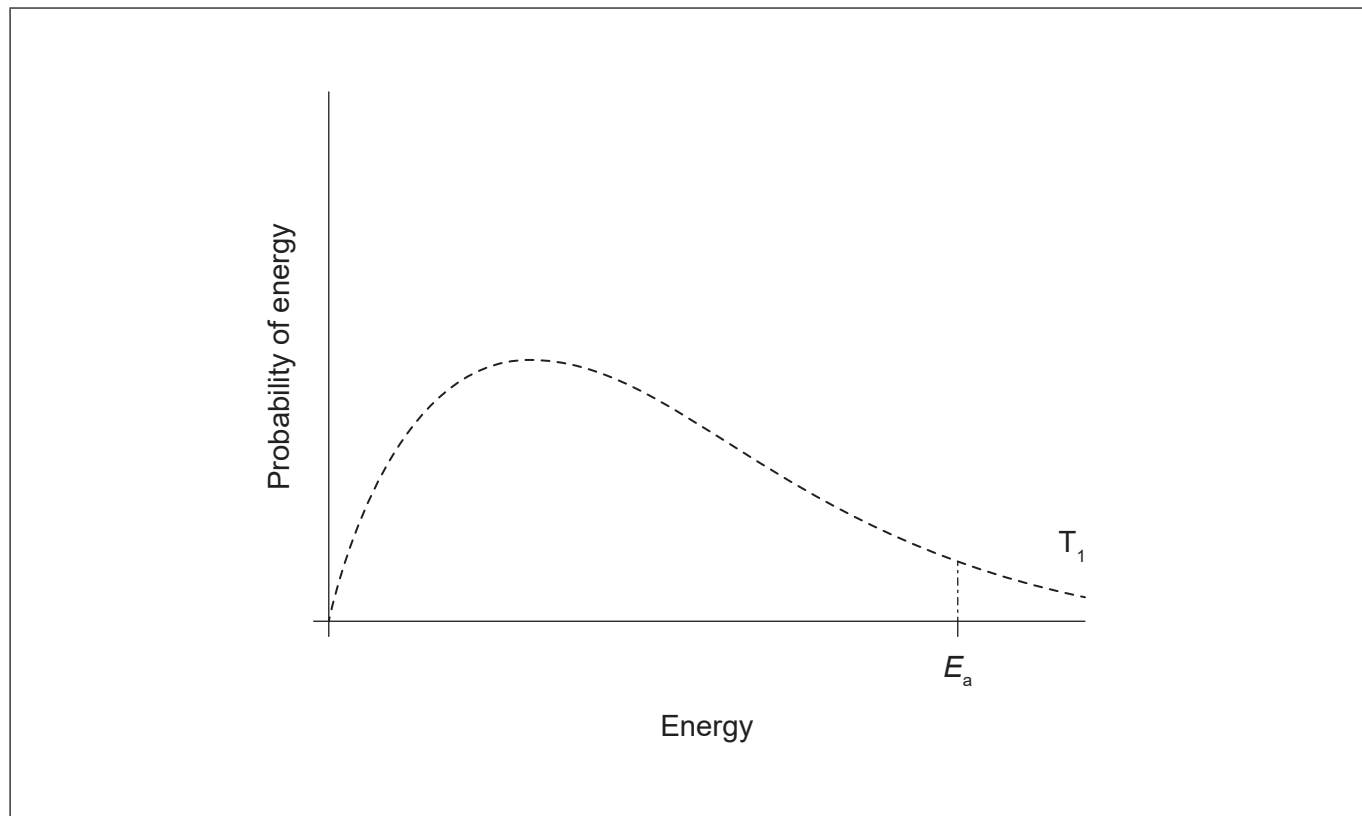
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4. Hydrogen peroxide can react with methane and oxygen to form methanol. This reaction can occur below 50°C if a gold nanoparticle catalyst is used.

(a) The diagram shows the Maxwell-Boltzmann curve for the uncatalyzed reaction.

Draw a distribution curve at a lower temperature (T_2) and show on the diagram how the addition of a catalyst enables the reaction to take place more rapidly than at T_1 . [2]



(b) The hydrogen peroxide could cause further oxidation of the methanol. Suggest a possible oxidation product. [1]

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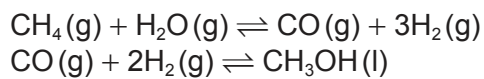


16EP09

Turn over

(Question 4 continued)

(c) Methanol is usually manufactured from methane in a two-stage process.



(i) Determine the overall equation for the production of methanol. [1]

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(ii) 8.00 g of methane is completely converted to methanol. Calculate, to three significant figures, the final volume of hydrogen at STP, in dm³. Use sections 2 and 6 of the data booklet. [3]

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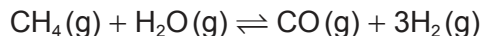
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(Question 4 continued)

(d) Consider the first stage of the reaction.



(i) Determine the enthalpy change, ΔH , in kJ. Use section 11 of the data booklet.

Bond enthalpy of CO = 1077 kJ mol⁻¹. [3]

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(ii) State the expression for K_c for this stage of the reaction. [1]

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(iii) State and explain the effect of increasing temperature on the value of K_c . [1]

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16EP12

5. Ethanol is obtained by the hydration of ethene, C₂H₄.

(a) (i) State the class of compound to which ethene belongs. [1]

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(ii) State the molecular formula of the next member of the homologous series to which ethene belongs. [1]

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(b) Justify why ethene has only a single signal in its ¹H NMR spectrum. [1]

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(c) Suggest **two** possible products of the incomplete combustion of ethene that would not be formed by complete combustion. [1]

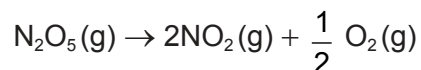
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(d) A white solid was formed when ethene was subjected to high pressure.
Deduce the type of reaction that occurred. [1]

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6. When dinitrogen pentoxide, N_2O_5 , is heated the colourless gas undergoes thermal decomposition to produce brown nitrogen dioxide:



- (a) Suggest how the extent of decomposition could be measured.

[1]

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- (b) Data for the decomposition at constant temperature is given.

$[N_2O_5] / 10^{-3} \text{ mol dm}^{-3}$	Rate / $10^{-3} \text{ mol dm}^{-3} \text{ min}^{-1}$
2.74	0.078
3.68	0.121
6.89	0.197
16.27	0.498
24.30	0.710

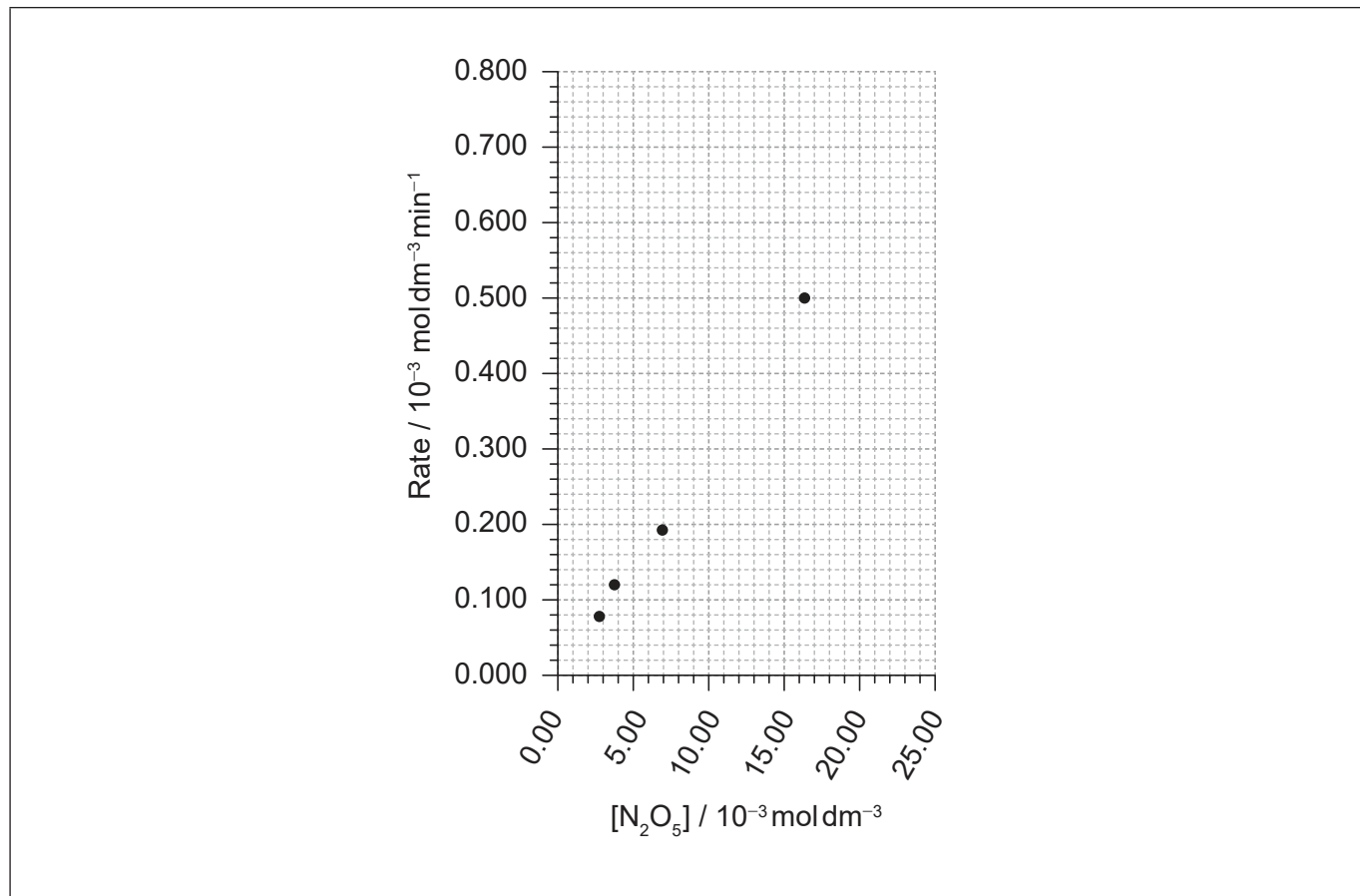
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(Question 6 continued)

(i) Plot the missing point on the graph and draw the best-fit line.

[2]



(ii) Deduce the relationship between the concentration of N_2O_5 and the rate of reaction.

[1]

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(iii) Outline why increasing the concentration of N_2O_5 increases the rate of reaction.

[1]

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References:

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16EP15

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16EP16